## TITLE OF THE INVENTION

Multi-Rotor Blade Stackable Vertical Axis Windmill

## CROSS-REFERENCE TO RELATED APPLICATIONS

This application is a ***continuation-in-part*** of co-pending U.S. Patent Application No. 10/064,180, filed on June 19, 2002, entitled Stackable Vertical Axis Windmill, which in turn claims the benefit of U.S. Provisional Application No. 60/299,383, filed on June 19, 2001. Both U.S. Patent Application No. 10/064,180 and U.S. Provisional Patent Application No. 60/299,383 are incorporated by reference in their entirety for all purposes as if fully set forth herein.

## STATEMENT REGARDING FEDERALLY SPONSORED RESEARCH OR DEVELOPMENT

Not applicable

## BACKGROUND OF THE INVENTION

a. Field of the Invention

The field of the instant invention is the generation of power using the motion of atmospheric wind. More specifically, the instant application teaches how to generate power from wind using a stackable, vertical axis windmill comprised of a braced external frame, rotors, bracing between rotor sections to increase the structural integrity of the complete multi-unit structure, an internal wind flow cavity, and wind guides to increase the efficiency.

b. Description of the Prior Art

As one would expect, the art in the area of windmills is plentiful. In the discussion that follows, the advantages and improvements of the various teachings of the prior art are summarized. Windmill design has progressed for hundreds of years. Various shapes and orientations have been studied including those with horizontal and vertical axis. Two basic types of windmill blades have been invented: drag-type blades and aerodynamic-type blades. The drag-type blades rely on the drag of the moving wind over the blades for transferring the kinetic energy from the wind to the blade, whereas the aerodynamic-type blades take advantage of the wind-foil shape of the blade to provide motion. Both types of blades have advantages and disadvantages that have been discussed in the literature.

A representative example of the art is U.S. Pat. No. 4,115,027 ('027) by Thomas that teaches a vertical windmill with airfoils mounted around a vertical axis. The support frame allows the airfoils to rotate around the central axis thereby generating the torque required to power an electrical generator. Attached to the support frame are stators that

direct the wind to the airfoil blades. The unit is self-supported, but '027 does not teach how to expand the power production from this single unit.

Ewers in U.S. Pat. No. 4,134,707 ('707) teaches a vertical axis windmill with a segmented design that can be incrementally added to increase the power production of the overall unit. Patent '707 uses a vertically rising exoskeleton with four external standards and at least two vertically spaced sets of radially converging ribs. The rotor in '707 is saw-toothed shaped to capture the movement of the wind. Although not claimed in '707, the specification teaches that the exoskeleton is to be braced with external guide wires. External guide wires are troublesome when attempting to implement the wind power unit in confined areas or where the added land requirements make the guide wires unworkable or unsightly.

U.S. Pat. No. 5,910,688 by Li teaches an improvement to the traditional farm windmill that is commonly seen in the countryside in the United States. More advanced technology is commonly found in the art as well, such as taught in U.S. Pat. No. 5,506,453 by McCombs. McCombs teaches a more modern version of the traditional farm windmill and includes a dual rotor, single support system. Both the Li and McCombs patent teach horizontal axis windmills. The term horizontal axis means that the wind causes a shaft to turn to transmit power, and the shaft is parallel with the wind, or horizontal to the ground. The most significant disadvantage with horizontal axis windmills is that they are very difficult to scale, that is, to increase generation capacity easily. To increase the energy producing power of horizontal windmills additional windmills must be added adjacent to

the location of the existing windmills that will increase the amount of land used thereby increasing the cost.

An alternative to the technology taught by Li and McCombs is the vertical axis windmill. U.S. Pat. No. 4,776,762 by Blowers is a representative technology for vertical axis windmills. Blowers teaches a power conversion turbine with a plurality of moveable blades. These blades open and close as the turbine rotates around its axis so as to make the best use of the wind. A single axis supports the turbine. In the configuration taught by Blowers, the turbine could be oriented so that the axis of rotation is vertical. In this way, the Blowers technology is scaleable by stacking several turbines vertically on the same axis.

Previous art that relates most closely to the instant invention is U.S. Pat. No. 6,242,818 ('818) by Smedley. Smedley teaches a vertical axis wind turbine having a plurality of blades around a vertical axis. The blades contain a wind catching surface and doors that open or close depending on the speed of the wind. The doors are inclined and are mounted on a pivot axis. As the windmill rotates at a higher velocity, the doors are forced outward thereby reducing the wind catching capability of the wind catching surface. In this manner, the '818 device is self-regulating. As the wind velocity increases past a critical velocity, the doors close to govern the rotational velocity of the windmill. Blowers also teaches the scalability of the device by stacking turbines vertically on the axis. The vertical axis is the only structural support of the device taught by Blowers.

The previous art suffers from several drawbacks. First, windmills that rely on horizontal axis turbines require additional land for scalability and additional machinery for transmitting the power from a horizontal axis to the ground for electricity generation. Second, the vertical axis windmills that rely on the rotor axis for structural support are not strong enough for the high velocity or gusty wind conditions common in many parts of the world. The instant invention addresses all of the disadvantages of the prior art by using a vertical shaft for transmission of power and an external frame to support the windmill.

The external frame is particularly important since this allows for the increased structural support of the windmill when two or more windmills are stacked. Stacking allows for more efficient use of costly land or rooftops. The external frame increases the overall strength of the windmill in contrast to the single member support, the power axis, used in prior devices.

BRIEF SUMMARY OF THE INVENTION

It is therefore an object of the present invention to provide a device for the generation of power using the motion of atmospheric wind. More particularly, it is an object of the present invention to generate power from wind using a stackable, vertical axis windmill comprised of a braced external frame, rotors, bracing between and with a stackable sections to increase the structural integrity of the complete multi-unit structure, an internal wind flow cavity, and wind guides to increase the efficiency.

BRIEF DESCRIPTION OF THE SEVERAL VIEWS OF THE DRAWING

Fig 1 shows the overall shape and framing of the Two-Rotor Stackable Vertical Axis Windmill.

Fig 2. shows a top view of the Two-Rotor Stackable Vertical Axis Windmill showing the bottom flange assembly of the rotor assembly that would be located above a given first rotor assembly.

Fig 3 shows the structure of the outside vertical supports showing relative placement of wind guides

Fig 4 shows the structure of the open frames.

Fig 5 is a top view of the rotor assembly.

Fig 6 is a side view of the rotor assembly showing one embodiment where the rotor panels are solid and a second embodiment where the rotor panels have openings formed by the rotor panels.

Fig 7 shows the bottom flange, flex coupling, and top flange.

Fig 8 shows a top view of a bottom flange.

## DETAILED DESCRIPTION OF THE INVENTION

### a. Description

The instant invention, the two-rotor stackable vertical axis windmill, is comprised of a frame structure **10**, rotor assembly **20**, a plurality of outer wind guides 31, and a plurality of inner wind guides **36**. Multiple instances of the instant invention can be stacked one upon the other to form a composite structure of up to 500 feet to harness the power of the moving wind. The description of the instant invention to follow will first focus on one instance of the invention and then later describe how multiple instances can be combined to form a larger structure capable of generating additional power.

The frame structure **10** as illustrated in FIG. 1 is comprised of a plurality of solid frames **30** and a plurality of open frames **40**. The solid frames **30**, as shown in FIG. 3, are comprised of a plurality of solid frame vertical members **32**, a plurality of solid frame horizontal members **33**, a plurality of solid frame cross members **34**, and a plurality of solid frame extended cross members **35**. The solid frames **30** are also comprised of the outer wind guides **31** and the inner wind guides **36**. The solid frames **30** support a wind guide panel 37 that serves to channel the wind inward to the rotor assembly **20**.

The open frames **40** are comprised of a plurality of open frame vertical members **42**, a plurality of open frame horizontal members **43**, and a plurality of open frame cross members **44**.

The solid frames **30** and the open frames **40** can be fabricated from wood, aluminum, composite materials, but most commonly are fabricated from steel. Connections used to fabricate the solid frames **30** and the open frames **40** are either threaded or welded connections. In one embodiment of the instant invention, five solid frames and ten open frames are connected to each other to form an essentially star shaped support structure with five apexes (shown in FIG. 1). In another embodiment, more solid frames and open frames can be connected to form structures with more than five apexes. In yet another embodiment, four open frames can be oriented to form a square structure, and four solid frames can project at various angles from the corners of the square to direct the air toward the rotor assembly. In an additional embodiment, three open frames can be oriented to form a triangle structure, and three solid frames can project at various angles from the corners of the triangle to direct the air toward the rotor assembly.

The rotor assembly **20** is comprised of a plurality of horizontal rotor assembly supports **25**, a rotor axis **23**, rotor panel assembly supports **56**, a bottom flange assembly **70**, a flex coupling assembly **72**, and a top flange assembly **71**. The horizontal rotor assembly supports **25** radiate outward from the top and bottom flange assemblies and connect the rotor assembly to the solid and inside frames. A plurality of open frame members **40** form the periphery of the rotor assembly **20**. Further comprising the rotor assembly is the rotor axis **23** that is rotatably mounted inside the frame flange. The rotor assembly **20** is located within the frame structure comprised of the open frame **40** and solid frame **30**

described above. More precisely, the rotor assembly **50** is axisymmetrically located within the frame structure with the rotor axis **23** aligned with the center of the frame structure. The rotor assembly can be further supported through the use of rotor support cables which are connected to various points on the rotor panels and rotor panel assembly supports. In a typical embodiment, rotor support cables are placed between opposite corners of the rotor panels and the rotor panel assembly supports.

The solid and open frames are further supported and stabilized with frame support cables. These frame support cables provide vertical and horizontal support and are typically placed from corner-to-corner forming x-bracing on the solid and open frames. In addition, guide wires are placed between the bottom corners of the rotor assembly **50** and the top flange assembly **71**. Outside support cables are placed circumferentially on the outside perimeter of the entire structure. All support cables are of sufficient diameter to provided the necessary support, but are not a significant impediment to the wind entering or leaving the structure.

Further comprising the rotor assembly is two or more rotors panel assemblies **50**. In one preferred embodiment of the instant invention, as shown in FIG. 5, the rotor assembly is comprised of two rotors panel assemblies **50**. The rotors panel assemblies **50** are, in turn, comprised of a rotor panel **52**, a trailing edge **53**, a leading edge **54**, and a windfoil **51**. The rotor panel **52** is of rectangular shape of thin material typically aluminum, steel or wood. In one embodiment of the instant invention, the rotor panel **52** is formed of solid material with no openings to allow wind to pass. In another embodiment, in particularly

windy climates, the rotor panels **52** can form rotor panel windows **61** to allow some of the wind to pass directly through the rotor assembly **50**. The trailing edge **53**, a leading edge **54**, and a windfoil **51** are elongated structures affixed to the rotor panel **52** parallel with the rotor axis and are typically aluminum, steel or wood. A plurality of rotor flange supports **56** connect the rotor panels assemblies **50** to a plurality of rotor plates **55** so that as the wind exerts forces on the rotor panel assemblies **50**, the plurality of rotor supports **55** turn the rotor axis **23** thereby transmitting the power.

The wind foil **51** is an elongated triangular structure running along the edge of the trailing edge parallel to the rotor axis **23**. The leading edge **54** is affixed to the rotor panel **52** on the opposite side of the rotor panel **52** from the wind foil **51**. The leading edge **54** is a thin rectangular sheet of material connected to the leading edge and oriented such that an angle of approximately 135 degrees is formed between the leading edge and the rotor panel **52**. In another embodiment, the leading edge **54** is integrally formed from a single sheet of aluminum or steel with the rotor panel **52**, but forms a structure with approximately 135 degrees between the main plane of the rotor panel **52** and the leading edge. The leading edge **54** is as long as the rotor panel **52**, but between one-half and one-eighth as wide as the main blade body.

The trailing edge **53** is a thin rectangular sheet of material with essentially the same dimensions as found on the leading edge **54**. The trailing edge **53** is connected to the rotor panel **52** and is oriented such that an angle of approximately 45 degrees is formed between the trailing edge **53** and the rotor panel **52**. The orientation of the thin

rectangular sheet of material connected to the leading edge is such that the thin rectangular sheet is orientated toward the main blade body. In another embodiment, the trailing edge **53** is integrally formed from a single sheet of aluminum or steel with the rotor panel **52** and the leading edge **54**. But when the trailing edge **53** is formed from a single sheet of material, the trailing edge forms an angle of approximately 45 degrees with the main blade body. Fig 5 illustrates a common embodiment showing a top view of the elongated triangular structure, thin rectangular sheet of material connected to the trailing edge, and the thin rectangular sheet of material connected to the leading edge.

In the rotor assembly **20**, the plurality of rotor blades assemblies **50** are attached via threaded or welded connections to the plurality of horizontal rotor supports **56**. The plurality of horizontal rotor supports **56** are rigidly attached to a plurality of rotor plates **55** by a welded connection or threaded connectors. The rotor plates **55** are affixed to the rotor axis by welded or threaded connections or in concert with a key to prevent the independent rotation of the rotor panels **52**, rotor supports **55**, rotor plates **55**, and the rotor axis **23**. In one common embodiment of the invention there are three rotor plates, a top, middle and bottom rotor plate. In this same embodiment, there are two parallel horizontal rotor supports **56** at approximately the top, middle and bottom portion of the rotor panel assemblies **50**, connecting the rotor blade assemblies **50** to a top, middle and bottom rotor plates **55**. In another embodiment of the instant invention, additional rotor plates may be added to the rotor assembly to increase the resistance to wind as it flows through the rotor assembly (see FIG 9). As many as four additional rotor plates may be added.

The bottom flange assembly **70**, top frame flange assembly **71** along with the flexible coupling **72** is shown in more detail in FIG. 7 and is shown how two rotor assemblies can be combined. The rotor axis **23** of a given rotor assembly passes through a top frame flange assembly **71**.

The top frame flange **71** assembly is comprised of a top flange plate **73** which is attached via a plurality of bolts to a top flange bearing **74**. The rotor axis is terminated with a top coupling **75** which is attached via a weld to the top of the rotor axis **23**. A corresponding rotor axis for the rotor assembly to be installed on top of the first rotor assembly is terminated on the bottom with a bottom coupling **76** which is attached via a weld to the bottom of the rotor axis **23**. Two rotor assemblies are connected by attaching the top of one rotor axis with the bottom of another rotor axis and securing the connection with a plurality of coupling bolts. To prevent the two rotor assembly from rotating independently, the top coupling **75** and bottom coupling **76** are fitted with a key to force the top coupling **75** and bottom coupling **76** to rotate with the rotor axis **23** at the same rotational speed. The top coupling **75** and bottom coupling **76** that are placed between each rotor assembly provide some flexibility so that each rotor assembly can move independently to a small degree.

As is shown in FIG. 8, the bottom frame flange assembly **70** is comprised of a bottom flange plate **24**, a split plate **21**, and a bottom flange bearing **22**. The bottom flange plate **24** is connected to the split plate via a plurality of bolts. The bottom flange bearing **22** is connected to the split plate and the bottom flange via a plurality of bolts. The split plate

**21** allows for removal of the bottom flange bearing **22** without disassembly of multiple rotor assemblies. To replace a bottom flange bearing **22**, all the bolts are first removed. Then the bolts in the flex coupling assembly **72** are removed and the bottom coupling **76** and key are removed. Both portions of the split plate **21** can be then removed. Lastly, the bottom flange bearing **22** then can pass through the opening in the bottom flange and off the bottom end of the rotor axis. A new bottom bearing can then be installed by reversing the procedure outlined above. The ability to replace the bottom bearing without complete disassembly of the entire stack of windmill assemblies is a unique and attractive feature of the instant invention.

The top bearing can also be removed using a similar procedure. The coupling bolts are removed along with the top coupling and key. Removing the top bearing bolts allows the top bearing.

When stacking additional entire assemblies of windmill one upon the other, the plurality of inside vertical members and inside vertical members can be connected via vertical support connectors to provide the necessary support for the entire structure. These connections are accomplished through bolted vertical support connectors so that windmill assemblies can be added or removed as necessary. If required, external guy wires can be employed to further steady the structure. Structures up to 500 feet can be created by stacking multiple windmill assemblies. A frame braced with internal cables only is capable of supporting a structure of up to 100 feet in height, but can be further supported by guide wires anchored to the ground.

In one embodiment to further support the structure when multiple windmill assemblies are stacked, interstitial cross braces, interstitial horizontal braces, and interstitial vertical braces are used to add support. Further a lace-up cable can be alternated between the outer vertical poles. Tension adjustment of the lace-up cable is provided at the base of the entire windmill structure.

b. Operation of the Invention

In the operation of the windmill, the wind passes across the air catching surface of the plurality of rotor blades and causes the rotors assembly to turn. The wind is caught by the leading edge **54** of the rotor blade assembly causing the rotor blade assembly to turn. In addition, as the wind as it passes over the wind foil **51** the wind also causes the rotor assembly to turn. A major advantage of this design is that even as wind is exiting the structure, the wind aids.in turning the rotor.

The rotor axis **23** in the rotor assembly **20** is then connected to an electrical generator that uses the rotational energy of the rotor axis to produce electrical power. The shape of the rotor blades and the inside rotor blades can vary depending on wind condition, but are most commonly triangular, rectangular or airfoil shaped. The rotors are angled so the wind passing over the rotor provides some lift in the vertical direction both as the wind enters and exits the rotor assembly.

The best mode of operation for the vertical axis stackable windmill is for a single rotor assembly to be housed inside the external frame that in turn supports the wind guide assembly. Two or more of the windmills may be stacked and connected with a rotor coupling shown in FIG. 7. Under normal conditions the wind enters one side of the instant invention and causes the rotor assembly to turn. Power is transmitted through the rotor shaft to an electric generator or other device that uses the power generated by the windmill.